Design of a CO_2 Injection System for Sequestration and Enhanced Oil and Gas Recovery Testing

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Project Objectives

- Design and build CO_2 injection system to support sequestration and enhanced oil and gas recovery testing at multiple sites in the Illinois Basin
  - Coal Bed Methane
  - Huff and Puff
  - Well Conversion
  - New Well / Pattern Flood
  - Deep Saline Reservoir
- Specify and obtain other required equipment
  - CO_2 Storage Tank
  - Line Heater
- Address safety concerns for liquid CO_2 service
- Predict pressures and phases in injection wellbore

Design Objectives

- Equipment must be portable and suitable for oil field use
- System must have flexibility to deliver CO_2 over a wide range of conditions:
  - 15 Mscf/d (0.9 ton/day) CO_2 vapor for Huff and Puff test
  - 2.2 MMscf/d (129 ton/day) CO_2 liquid for Deep Saline Reservoir test
- CO_2 Storage
  - Maximum capacity required for test flexibility
  - Portable storage tank needed to minimize transportation and site support costs
- Line Heater
  - Must vaporize some or all of CO_2 for tests that require vapor injection
  - Must heat CO_2 up to near ambient temperature for realistic simulation of future CO_2 injection projects

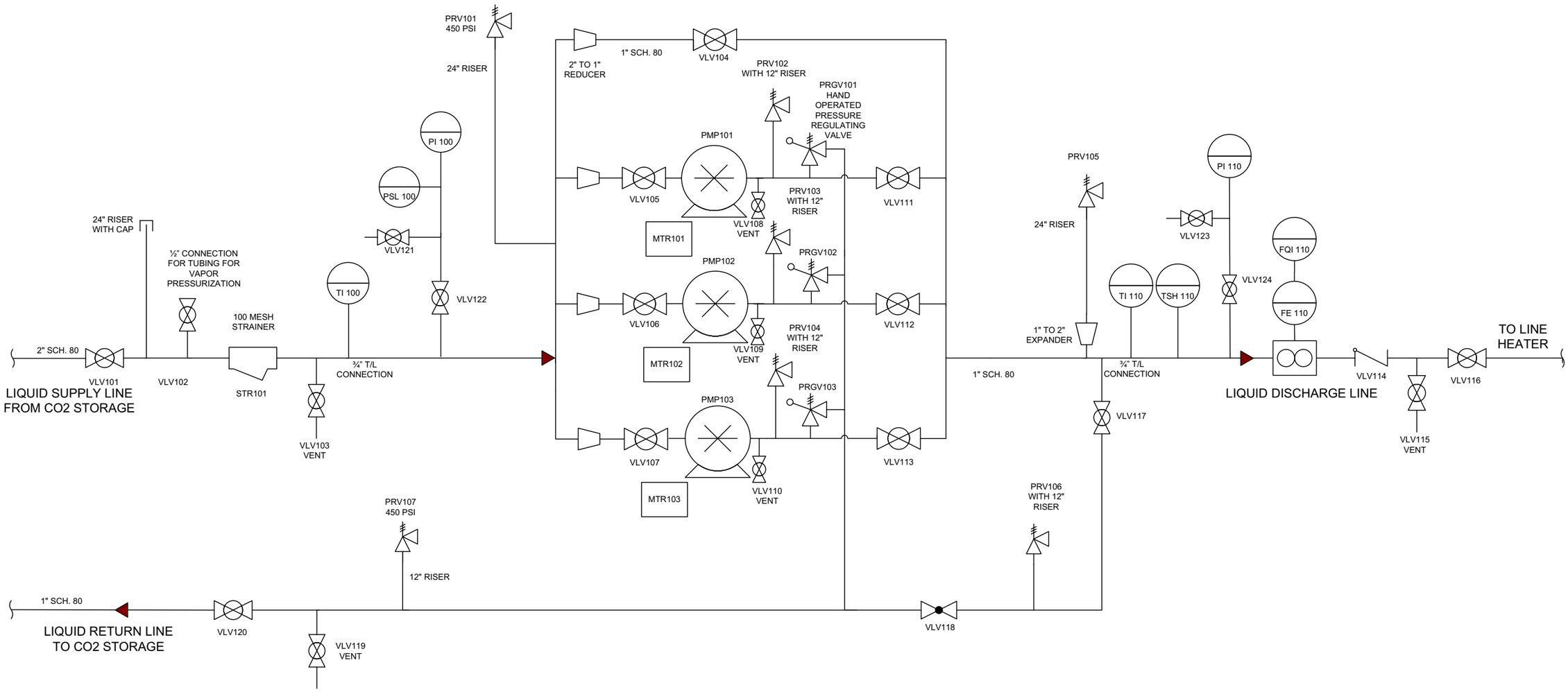
Equipment Overview

- Pump Skid
  - 3, single piston cylinder pumps in parallel, 7 gpm (69 lb/min) capacity each
  - Pressure regulated bypass valves for constant pressure injection
  - Return line with globe valve for constant flow rate injection over a wide range of flow rates
  - Liquid flow meter with flow transmitter and totalizer
- CO_2 Storage Tank
  - 60 ton capacity
  - Portable tank to reduce transportation and site support costs
- Line Heater
  - Propane fired, 250 MBtu/hr capacity
  - Suitable for water or glycol service
  - Skid and lift lugs added for increased portability

Safety Design Considerations for Liquid CO_2 Service

- Liquid CO_2 will be at 0 ^oF and range from 300 psia to 1,000 psia in the pump skid piping
- If liquid CO_2 becomes trapped in the lines, it will heat rapidly and pressure will rise
  - System is designed with automatic pressure relief valves located every place that liquid CO_2 has the potential to be blocked in
  - PRV discharges will be routed to divert flow of cold vapor CO_2 that would exit the PRV's in order to reduce the risk of personnel exposure
- Normal shutdown procedures will vent liquid CO_2 from bottom of pipes to prevent equipment exposure to temperatures lower than design conditions
- Ambient CO_2 monitors will be installed at four site locations and will alarm if elevated levels of ambient CO_2 are detected

Pump Skid Process Flow Diagram



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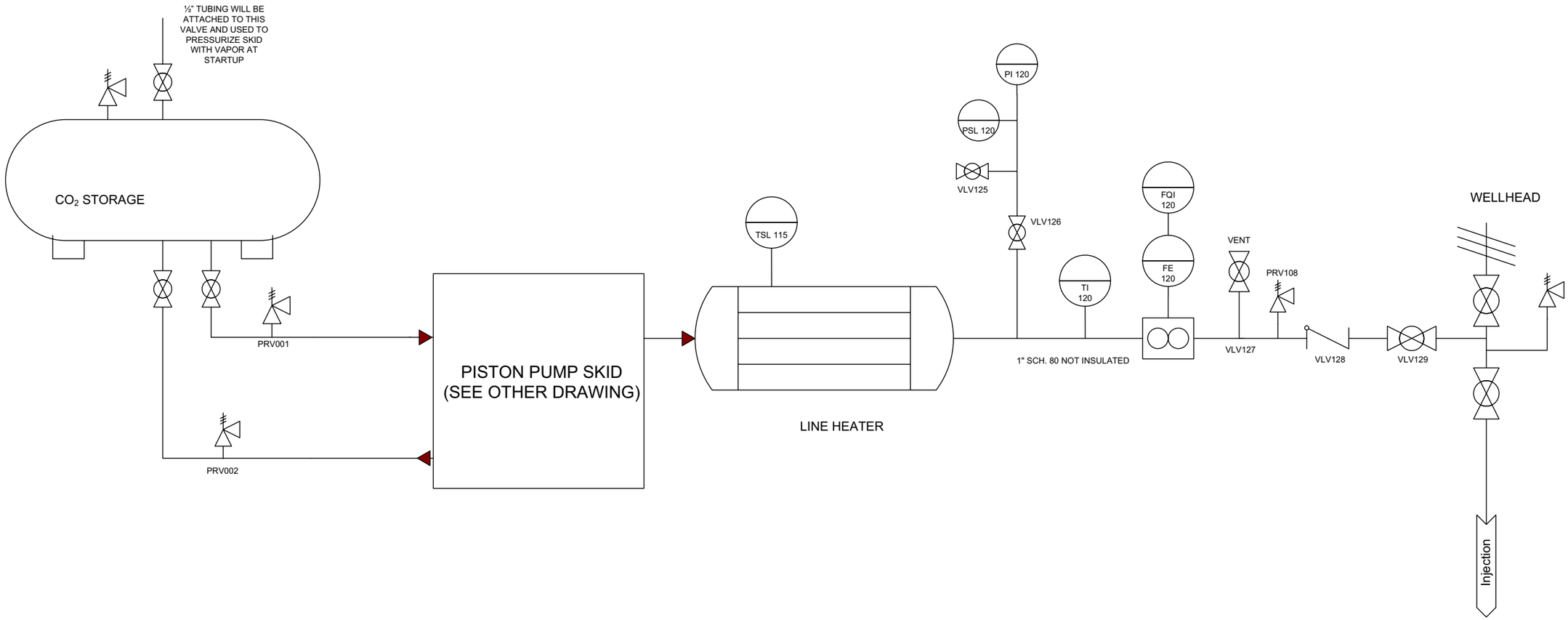
Overall Process Flow Diagram



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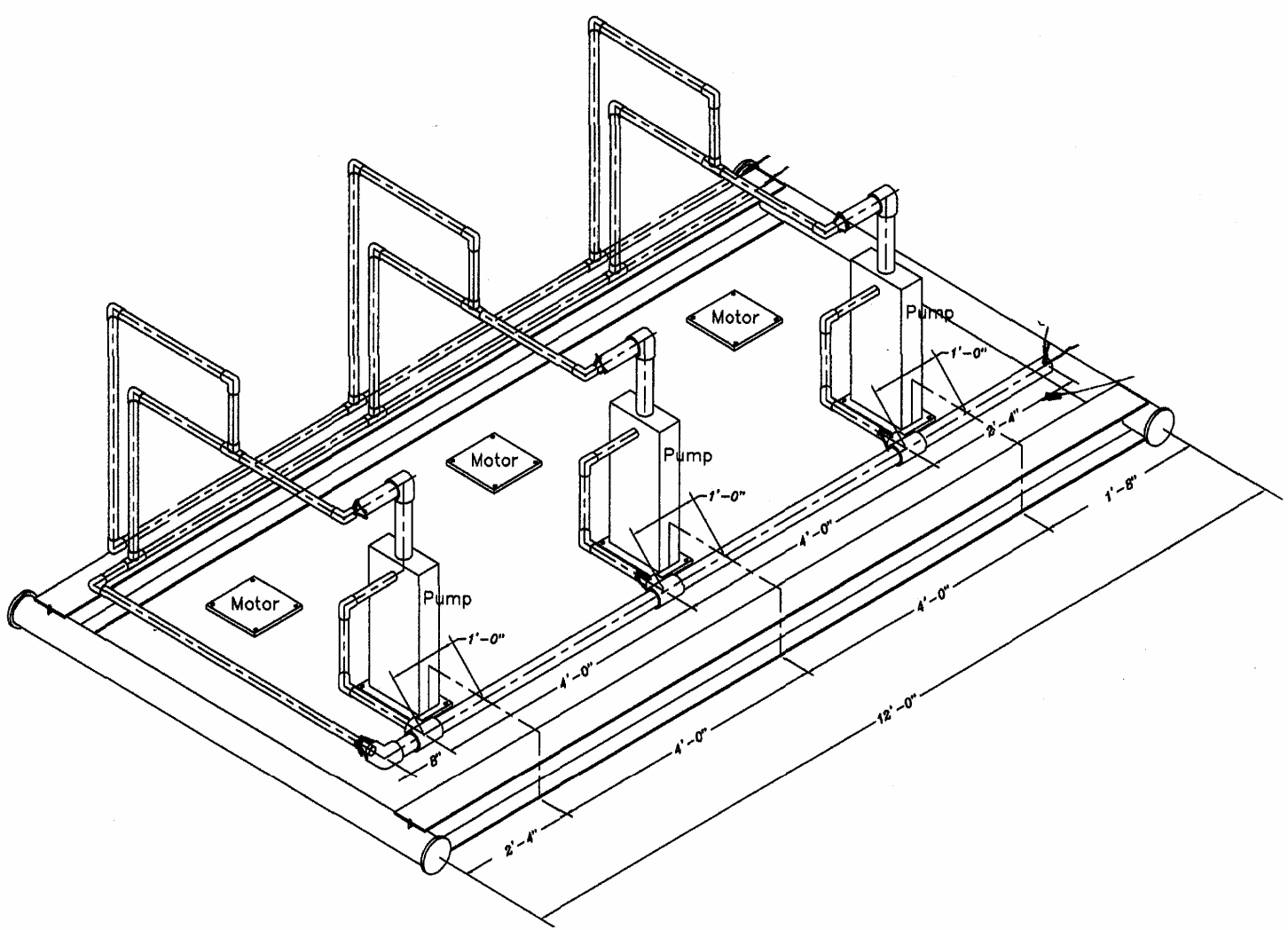
Simplified Isometric Pump Skid Drawing



Skid dimensions: 6’ wide x 12’ long

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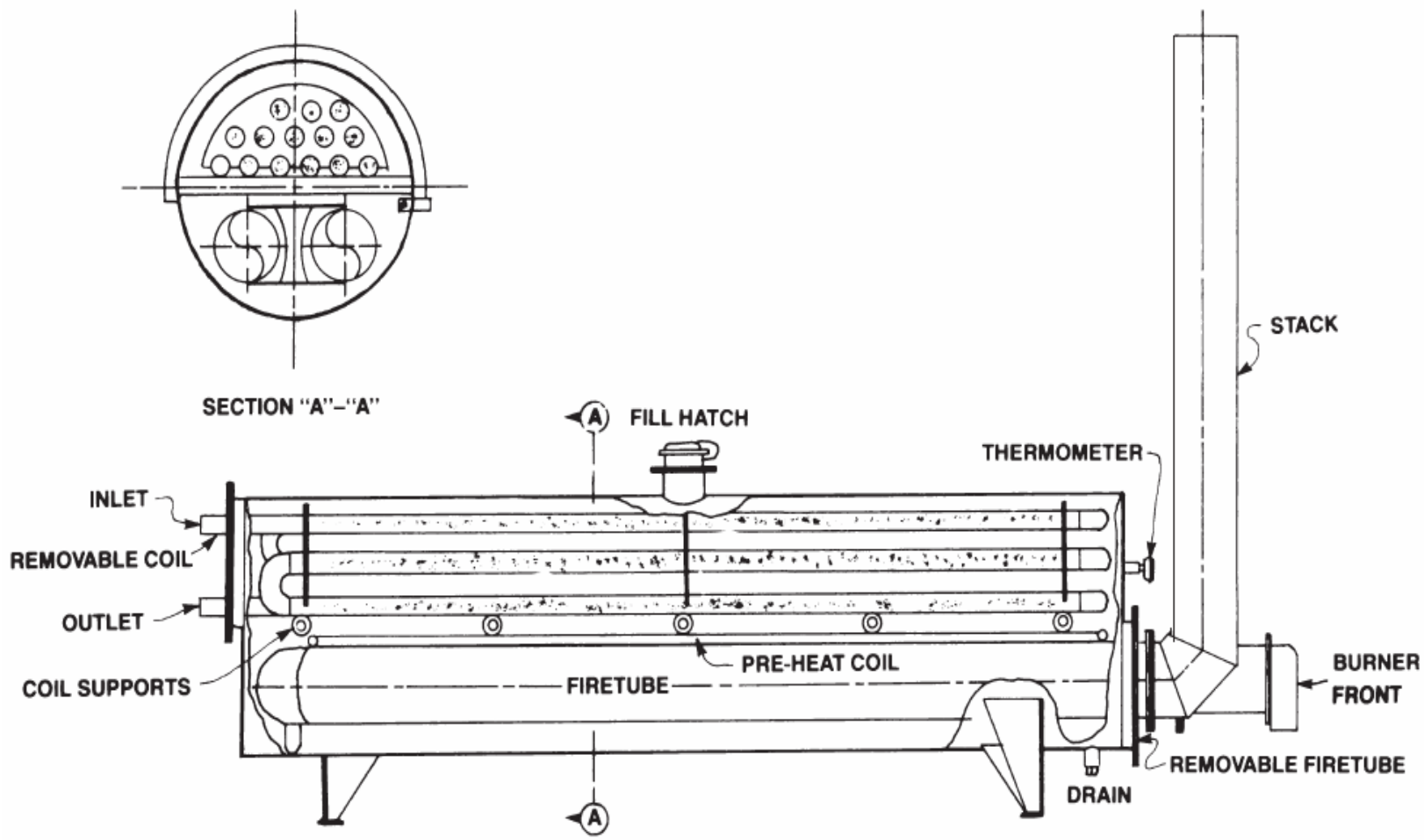
60 Ton Portable CO_2 Storage Tank

Line Heater Schematic



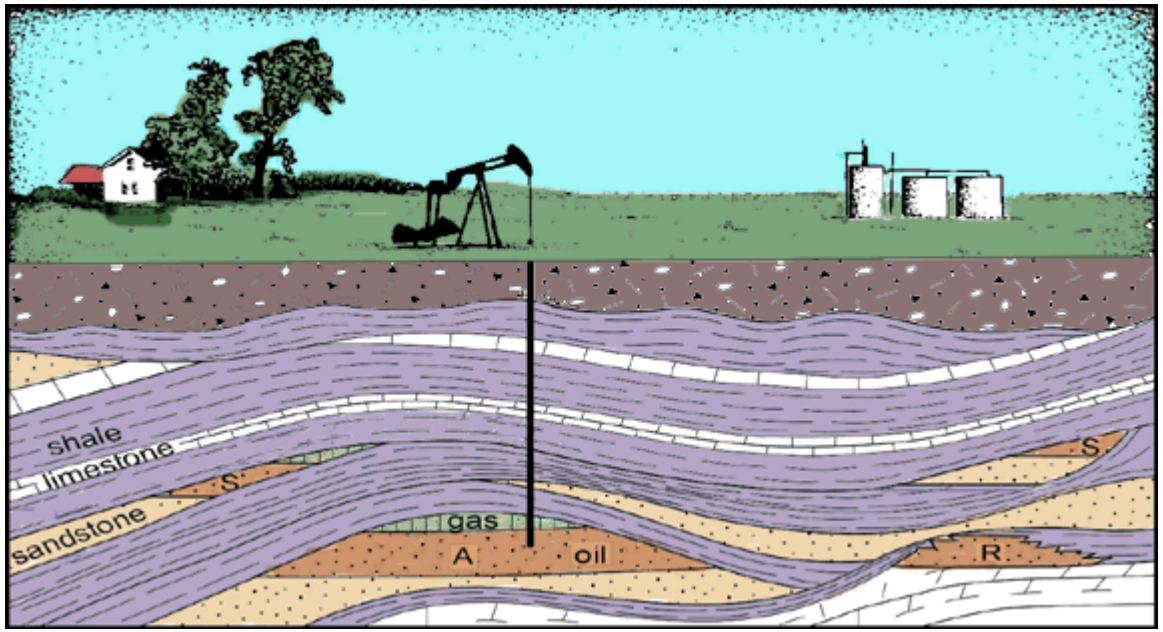
Source: GPSA Engineering Data Book, 12th Ed, Fig. 8-32

250 MBtu/hr, Propane Fired Line Heater

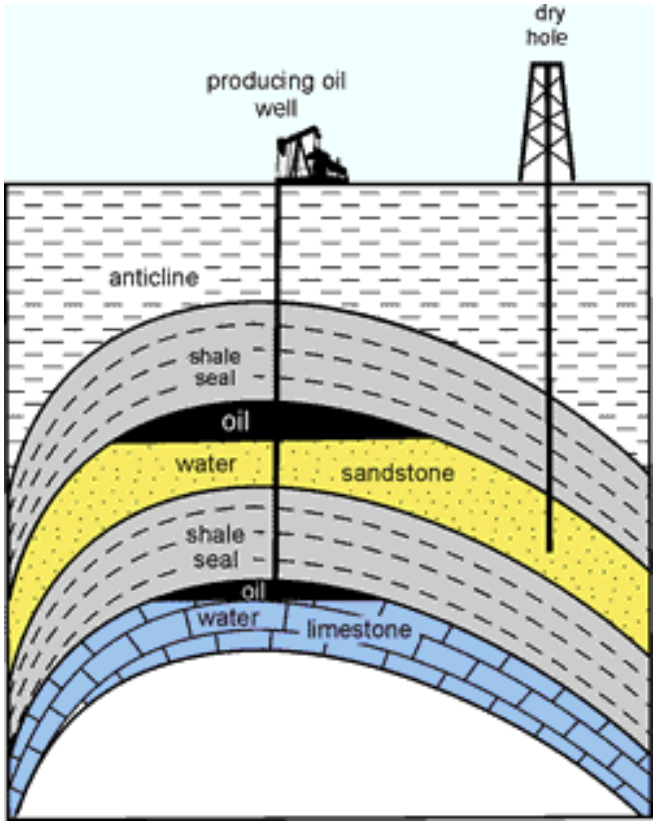
24” diameter, 8’ long, 1,800 lb. dry weight on skid

Wellhead

Reservoir Schematics



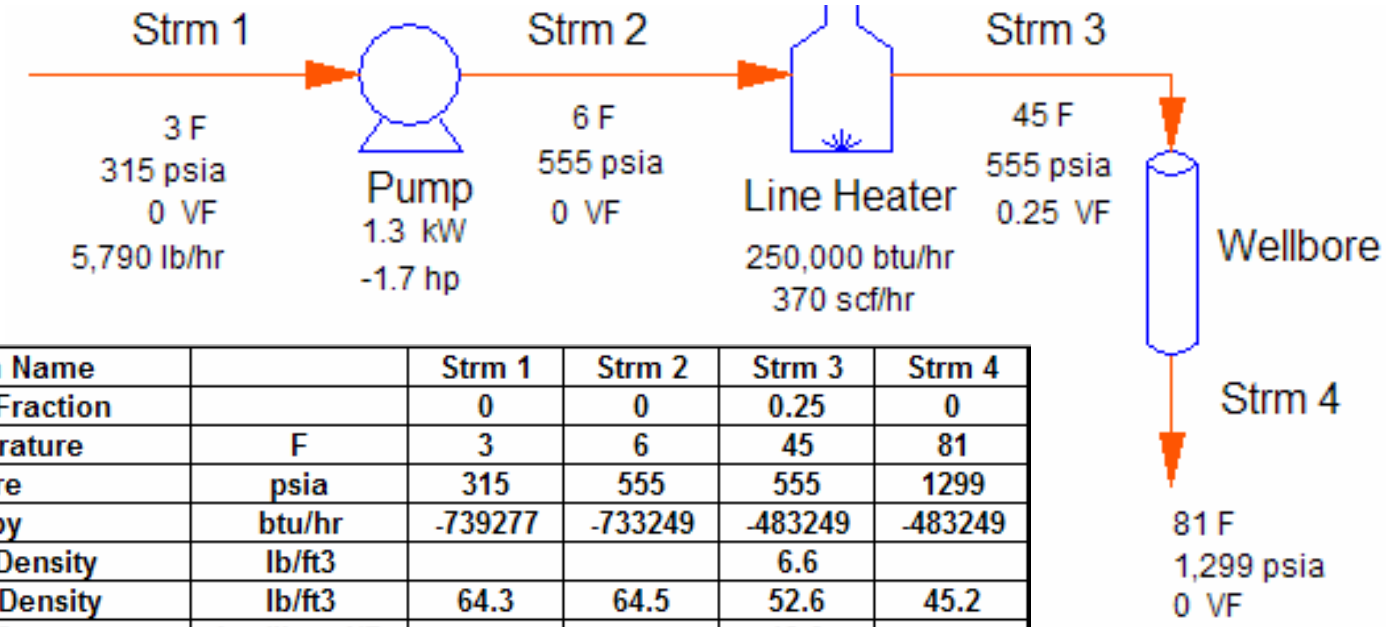
Impervious rocks like shale trap oil and gas in crests or upwarps of rock layers.
A=anticline trap. R=reef trap. S=stratigraphic trap



The folded rock layers trap the oil, which is lighter than water and floats at the top of the reservoir.

Source: ISGS, Geobits 8 and 9

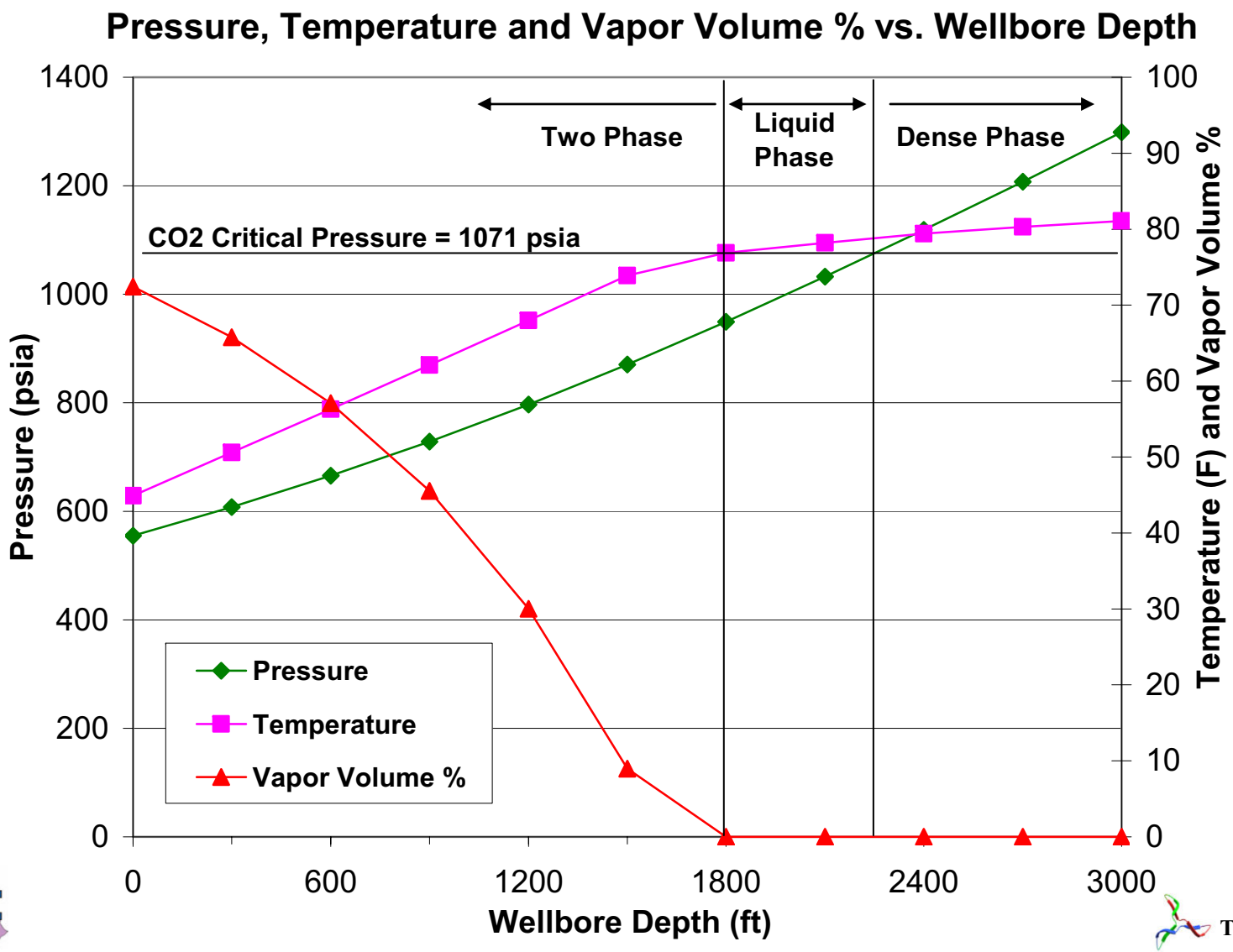
Simulation Results – New Oil Well Case



Stream Name		Strm 1	Strm 2	Strm 3	Strm 4
Vapor Fraction		0	0	0.25	0
Temperature	F	3	6	45	81
Pressure	psia	315	555	555	1299
Enthalpy	btu/hr	-739277	-733249	-483249	-483249
Vapor Density	lb/ft3			6.6	
Liquid Density	lb/ft3	64.3	64.5	52.6	45.2
Vapor Cp	btu/lbmol/R			13.9	
Liquid Cp	btu/lbmol/R	21.4	20.9	28.7	55.9
Vapor Viscosity	cP			0.016	
Liquid Viscosity	cP	0.121	0.121	0.086	0.069
Liquid Flowrate	gal/min@STP	14.0	14.0	10.5	14.0
Molecular Weight		44.0	44.0	44.0	44.0
Molar Flowrate	lbmol/hr	131.5	131.5	131.5	131.5
Mass Flowrate	lb/hr	5789	5789	5789	5789

Simulation Package: WinSim Design II v 9.32

Simulated Wellbore Conditions – New Oil Well Case



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Conclusions

- Pump skid has been designed to provide maximum flexibility over a wide range of operating conditions
- System design incorporates safety requirements for liquid CO_2 service
- Pump skid, CO_2 storage tank, and line heater selections ensure oil field suitability and maximum portability for multi-site, four year project
- Pump skid completion is scheduled for mid-May 2006
- Line heater and CO_2 storage tank will also available by mid-May 2006